LIST OF THE RELEVANT PRIOR DOCUMENT

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(54) [TITLE OF THE INVENTION] DISPLAY APPARATUS

(57) [ABSTRACT]

[PROBLEM TO BE SOLVED] In a projection-type display apparatus, to display an aberrationfree image even in a simple optical system.

[MEANS FOR SOLVING PROBLEM] In a structure in which an image optically modulated by a liquid crystal panel 12 is finally projected and displayed on a screen 16 via a projection lens 13, an image containing aberration projected from the lens 13 is corrected when the image is reflected at a mirror 14. In other words, the shape of the mirror 14 is formed so as to correct aberration generated at the lens 13. Configuring like this, an aberrationfree image can be magnified to display it on a large screen without utilizing a complex and expensive optical system.

[SCOPE OF CLAIMS]

[Claim 1] A display apparatus comprising:

a lens; and

a curved mirror surface,

wherein an image projected via said lens is once reflected at said curved mirror surface, and formed an image on the projection surface.

[Claim 2] A display apparatus comprising:

a lens; and

a curved mirror surface,

wherein aberration of an image generated at said lens is corrected by reflecting it on said curved mirror surface.

[Claim 3] A display apparatus having a structure in which an image is magnified and displayed, comprising:

a lens for magnifying said image; and

a mirror surface for reflecting an image transmitted through said lens,

wherein said mirror surface is of a convex shape for correcting aberration of said image transmitted though said lens.

[Claim 4] A display apparatus wherein an image transmitted though a lens is reflected at a mirror surface of a predetermined shape, to correct aberration of said image.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD OF THE INVENTION] An invention disclosed in this specification is related to a display apparatus in which an image is magnified and projected. For example, an invention is related to a display apparatus in which an image formed by a liquid crystal panel is magnified by a lens for projection.

[0002]

[PRIOR ART] Conventionally, there is known a structure in which an image optically modulated by the liquid crystal panel is magnified by a lens and projected on a screen. A simple example of such a structure is shown in Fig. 2(A).

[0003] In a structure shown in Fig. 2(A), light 22 emitted from a lamp 21 is optically modulated by a liquid crystal panel 23 to

form a predetermined image, and the image is projected on a screen 25 by using a projection lens 24. An image projected on the screen 25 can be seen from a direction indicated by reference numeral 26 or the projection lens 24.

[0004] As the projection lens 24, the use of a mere convex lens shown in Fig. 2(A) leads to the most simple structure. In such a structure, accuracy or characteristics of the projection lens is important. Generally, a lens generates spherical aberration, so that the magnified image cannot be projected in a perfect condition.

[0005] The aberration means that light is not converged to one point in an optical system. As the aberration, there are spherical aberration, coma, astigmatism, field curvature, backing distortion and chromatic aberration. As specific phenomena caused by aberration, there are a distorted image and a colored image.

[0006] For example, as a specific example of the chromatic aberration, there is a phenomenon that an image is colored in case of observing stars on a telescope. This phenomenon is resulted from the fact that different wavelength components transmitting through the lens have different refractive index with respect to materials making the lens.

[0007] The problems of the aberration as above are popped up in a case where a large lens is used. Therefore, a serious problem is caused in a case of displaying an image on the large screen.

[0008] To solve the problem of the aberration, it has been adopted a method in which a number of lenses 27 and 28 are combined as shown in Fig. 2 (B). Using this method, the aberration can be corrected to a range within which the aberration is allowable, by increasing

the number of lens to be combined. However, such combination of the plural lenses yields complex and expensive projection lens. In addition, it gives rise to a problem that realization of a large lens becomes difficult.

[0009] Therefore, in view of practicality and productivity, the most ideal way is to configure an optical system by a single lens 24 as shown in Fig. 2(A).

[0010] However, the simple structure made up of the single lens 24 shown in Fig. 2 (A) generates aberration that becomes in issue for the practical use.

[0011]

[PROBLEM TO BE SOLVED BY THE INVENTION] An object of the present invention disclosed in this specification is to provide a structure in which an image is magnified by using a lens and projected, and which is able to correct the aberration generated at the lens. Particularly, the present invention provides this structure as a technique at a low cost.

[0012]

[MEANS FOR SOLVING THE PROBLEMS] In the structure according to the present invention includes a lens; and a curved mirror surface; wherein an image projected via the lens is once reflected at the curved mirror surface, and formed an image on the projection surface.

[0013] A feature of the above structure is in that aberration generated at the lens is corrected by reflecting an image containing the aberration at a mirror surface formed in a predetermined shape.

[0014] As a lens, there are a mere convex lens for magnifying an

image, a combination of the convex lens and an aberration-correcting concave lens, a lens formed in a special shape different from the convex lens and the concave lens, and a lens combined and joined these lenses. In other words, the lens in this specification means one with a capability capable of optically magnifying an image by transmitting the image therethrough.

[0015] The shape of the mirror surface and the curvature thereof should be determined in accordance with the optical characteristics of the lens to be used. Namely, the lens must be of the shape which is able to correct the aberration generated at the lens. This shape can be determined by a computer simulation.

[0016] In case of the mirror surface, since the light does not transmit therethrough, the aberration due to the transmitted light is not generated.

[0017] Then, properly setting the shape permits correction of the aberration generated when an image is transmitted through the lens. This correction is enough if a practical effect can be obtained even though it is not perfect.

[0018] Another structure of the present invention includes a lens; and a curved mirror surface; wherein aberration of an image from the lens is corrected by reflecting the image at the curved mirror surface.

[0019] Yet another structure of the present invention includes a lens for magnifying the image; and a mirror surface for reflecting an image transmitted through the lens; wherein the mirror surface is of a convex shape for correcting the aberration of the image transmitted through the lens.

[0020] Still further, in other structure of the present invention, an image magnified by a lens is reflected at a mirror surface of a predetermined shape to project the image whose aberration is corrected.

[0021]

[EMBODIMENTS OF THE INVENTION] As shown in Fig. 1, when an image optically modulated by a liquid crystal panel 12 is magnified by a projection lens 13 and projected on a screen 16, a reflection mirror 14 is curved so as to correct aberration generated at the projection lens 13. Configuring like this, the aberration generated at the projection lens 13 can be corrected by the reflection mirror 14, and image containing no aberration or less aberration can be projected on the screen 16.

[0022]

[EMBODIMENTS]

[First Embodiment] Fig. 1 shows a schematic diagram of a projection-type display apparatus of the first embodiment. In the structure shown Fig. 1, light emitted from a light source 11 which is enclosed in a cabinet 10 and project white light is optically modulated by a transmission liquid crystal panel on which a color image can be displayed to form the color image, and the image is magnified by the projection lens 13. Further, the magnified image is reflected at the reflection mirror 14 of a predetermined shape, then the image reflected at the reflection mirror 14 is reflected at a plane mirror 15 to project an image on the screen 16.

[0023] In the structure shown in Fig. 1, even if a low-cost projection lens 13 is used, the aberration generated there can be

corrected when the image is reflected at the reflection mirror 14 of the predetermined shape.

[0024] The curvature of the reflection mirror 14 should be determined so as to correct the aberration generated at the lens 13. However, to form the reflection mirror 14 in the predetermined shape is an easy task, and thus the production cost thereof can be decreased. In addition, there is an advantage that the aberration is not generated at the reflection mirror 14. The reflection mirror 14 is convex in shape. However, the shape of the reflection mirror is determined in relation to the lens 13, so that it is not merely limited to a concave in shape or a convex in shape. Similarly, the shape of the lens 13 is also determined in relation to the reflection mirror 14. In other words, the lens 13 and the reflection mirror 14 must be designed as a mutual complement.

[0025] The liquid crystal panel shown in the present invention is an active-matrix-type and is able to display in color.

[0026] In the structure shown in Fig. 1, an example is shown in which the reflection mirror 14 is curved. In such a structure in which two reflection mirrors 14 and 15 are used, the first reflection mirror 14 can be made small. In order to form the reflection mirror into a finely curved surface, a mirror of the moderate size is rather favorable. Therefore, as a curved reflection mirror shown in the structure of Fig. 1, selection of the first reflection mirror 14 is preferable.

[0027] However, if succeeded in forming a reflection mirror in the predetermined shape, the reflection mirror 14 may be formed into a plane reflection mirror, and reflection mirror 15 into a curved

one. Further, in addition to the reflection mirror 14, the reflection mirror 15 may be formed into a curved one.

[0028] [Second Embodiment] This second embodiment directs to a structure in which a projection is done by utilizing an integrated liquid crystal panel made up of three liquid crystal panels for RGB formed by one substrate. Fig. 3 shows a schematic diagram of a projection-type display apparatus of the second embodiment.

[0029] In the structure shown in Fig. 3, firstly, light emitted from a light source 301 which emits white light is separated into GBR by dichroic mirror 302 to 304. Then the each of the separated light is optically modulated by a liquid crystal panel 305 having integrated three liquid crystal panels corresponding to RGB. Subsequently, each of the images corresponding to the optically modulated RGB is composed by a mirror 306 and half mirrors 307 and 308, and projected from a projection lens 309. The image from the projection lens is reflected at a reflection mirror 310 and a plane mirror 311 to magnify and project it on a screen 312.

[0030] Here, the shape of the reflection mirror 310 is determined so as to correct the aberration generated at the projection lens 309. Configuring like this, at the time the image is reflected at the plane mirror 311, it is possible to form an aberrationfree image, or corrected to a predetermined degree. Then the color image reflected at the plane mirror 311 is projected on the screen 312.

[0031] In the structure shown in Fig. 4, just one projection lens 309 is required and a low-cost lens can be available as the projection lens 309. The optical system for magnifying the image can be simplified. In addition, the projected image is of

aberrationfree high picture quality. Therefore, despite aberrationfree high picture quality a display apparatus can be realized at a low-production cost.

[0032] [Third Embodiment] This third embodiment directs to an embodiment in which the present invention disclosed in this specification is adapted to the projection-type display apparatus, which is able to project a color image or stereoscopic image. Fig. 4 shows a schematic diagram of the third embodiment. Fig. 4 shows three sides view of a projection-type display apparatus of the third embodiment.

[0033] In Fig. 4, reference numeral 400 denotes a cabinet of the apparatus, in which the structure shown in this third embodiment is enclosed therein. In Fig. 4, white light emitted from a light source 401 is reflected at a semitransmission mirror 410 and mirror 411, and is further separated into G, B, R by dichroic mirrors 402, 403 and 404.

[0034] While in Fig. 4 the dichroic mirrors 402 to 404 are shown as one set, actually, another one set of dichroic mirror is positioned. In other words, there are dichroic mirrors 402 to 404 as one set to separate the light from semitransmission mirror 410, and the dichroic mirror (not shown) as one set to separate light from the mirror 411. In this way, six beams of RGB are formed as two sets.

[0035] These six beams (beams corresponding to the two sets of RGB) are incident on a liquid crystal panel 405. The six liquid crystal panels are integrated by using the same glass substrate. Namely, two sets of three liquid crystal panels of RGB are formed by using

the same glass substrate.

[0036] The images obtained by transmitting them these six liquid crystal panels are projected directly from the optical system 406 in which six projection lenses corresponding to each of the images are arranged. In a projection lens unit constituting the optical system 406 two lenses are arranged for one doted line. This projection lens unit is placed to six portions, one of which is indicated by reference numeral 407. That is, the projection lens unit is placed in correspondence with six panels integrated on each of liquid crystal panel 405.

[0037] The light emitted from the optical system 406 (six beams) is reflected at a reflection surface 408 formed in the predetermined curved shape, and projected on a screen (projection surface) 409. Each of the images is composed on the screen 409 to form a color image.

[0038] In the structure shown in Fig. 4, an image outputted from the liquid crystal panel 405 is subjected to an optical effect at the first and second lens (not shown) provided in the optical system 406 and a reflection surface 408.

[0039] In the third embodiment, the following structure has been taken to reduce aberration inevitably generated in a lens system. Here, a simple structure is taken for brevity's sake.

[0040] Fig 5 shows a structure in which an image formed by two liquid crystal panels 501 and 502 is finally projected on a screen 508. While in Fig. 5 an example is shown where two images are composed finally on the screen 508, the same basic structure is taken even when two or more images.

[0041] In a structure shown in Fig. 5 the image optically modulated by the liquid crystal panel 502 is magnified by the first lens 504 and the second lens 506. Then these images are reflected at a curved reflection surface 507 and projected on the screen 508.

[0042] On the other hand, the image optically modulated by the liquid crystal panel 501 is magnified by the first lens 503 and the second lens 505. Then these images are reflected at the curved reflection surface 507 and projected on the screen 508. These two images are composed on the screen 508 and displayed on the screen as one image.

[0043] Here, an important thing is in that a variety of design parameters for 504 and 506 and the shape of the reflection surface 507 are designed so as to correct the aberration by reflecting the image transmitted through the lenses 504 and 506.

[0044] Similarly, a variety of design parameters for 504 and 506 and the shape of the reflection surface 507 are designed so as to correct the aberration by reflecting the image transmitted through the lenses 504 and 506.

[0045] As a matter of course, the lenses 503, 504, 505, 506 take slightly different design parameters. In addition, the reason why two lenses are used for one image here is to have more freedom in the optical design to correct the aberration. However, an increase in the lens results in complex optical design and higher production cost, so that the least number of the lens is preferably.

[0046] Note that, in Fig. 5, each lens 503 to 506 is of simple convex shape, but actual lens has a necessary optical characteristic. In other words, the shape is not limited to the simple convex lens.

[0047] The structure shown in Fig. 4 is one that is made by utilizing basically the structure in Fig. 5, and the image from the each liquid crystal panel is formed into an image containing the least aberration by two lenses arranged in the optical system 406 and the curved reflection surface 408 and composed on the screen 409.

[0048] Each of the lens must be designed taking into consideration the relationship to the reflection surface 408, so as to finally project the aberrationfree image on the screen 409.

[0049] In the structure in the third embodiment, since two sets of the RGB images are composed, display can be made with high-intensity with defects of the liquid crystal panel being unobtrusive.

[0050] Further, the structure shown in Fig. 4 can be applicable to one so as to display a stereoscopic image. Namely, since two RGB sets are displayed on the screen 409, a color image for right eye and that for left eye are displayed on the screen 409 respectively, and the image can be seen as a telescopic image on the screen 409 by a glass which can separate these two image. In addition, the telescopic image can be displayed by making the screen 409 with a reticular screen.

[0051] Further, the structure shown in Fig. 4 can be applicable to a structure so as to display a structure in which an stereoscopic image is displayed by making a time division display of the two color images.

[0052] In the structure shown in Fig. 4, even if it attempts to display a large screen, an aberrationfree display can be made. In addition, since the structure of the lens system is simplified

(generally four or more lenses are used), the cost can be reduced. Further, since the larger image can be displayed by using a curved reflection surface, it has an advantage that expensive large diameter lenses are not required.

[0053] [Fourth Embodiment] The fourth embodiment shows an example of a case where the reflection mirror shape is different from the structure shown in Fig. 1. In Fig. 1, the reflection mirror of curvature in a predetermined direction is exemplified as a shape of the aberration-correcting reflection mirror. Namely, a case is shown where the shape of the aberration-correcting reflection mirror is concave, or convex.

[0054] However, in accordance with the lens to be used, more complex shape of the reflection mirror is required. Fig. 6 shows a schematic diagram of a projection-type display apparatus of the fourth embodiment. In Fig. 6, reference numeral 600 denotes a cabinet of the apparatus, and reference numeral 606 a screen (surface to be emitted) on which an image is projected.

[0055] The image is formed by optically modulating the light emitted from a light source 601 by using a liquid crystal panel 602. The image optically modulated by the liquid crystal panel 602 is reflected at an aberration-correcting reflection mirror 604, and a plane reflection plate 605 via a projection lens 603, and then projected on the screen 606.

[0056] A feature of the fourth embodiment is in that the shape of the reflection mirror 604 is made wavy to correct the aberration generated at the projection lens 603. The shape is emphasized in Fig. 6 and determined by the aberration of the image from the

projection lens 603.

[0057] Further, the aberration of the image from the projection lens 603 is not necessarily generated only at the projection lens 603. In other words, on the reflection mirror 604, the aberration of an image can be corrected at the time the image is incident on the reflection mirror 604. However, in this case, since the aberration generated other than the lens 603 should be considered, the optical design is complicated.

[0058] [Fifth Embodiment] Fig. 7 shows an optical layout drawing of the fifth embodiment, and a schematic diagram of a single plate projection-type display apparatus.

[0059] Light emitted from the light source 700 is separated into read, green, and blue respectively via color-separating dichroic mirrors 702a and 702b, and respectively incident on a read liquid crystal panel 704b, a green liquid crystal panel 704c, and a blue liquid crystal panel 704a to be optically modulated. The image light optically modulated by each of the liquid crystal panels 704a, 704b and 704c is composed by a color-composing dichroic mirror 702e and 702d, reflected at a curved reflection mirror 706 via a projection lens 705, and projected on a screen 707 to display a color image.

[0060] Where, reference numeral 701 denotes a UV filter, and reference numerals 703a and 703b total reflection mirrors, and reference numerals 707a and 707b condenser lenses.

[0061] In addition, the shape of the reflecting surface is determined so as to correct the aberration generated at the projection lens 705. As a result, the aberration generated at the

projection lens 705 is corrected by reflecting an image containing the aberration at the reflection mirror 706, and clear image containing no distortion or color saturation can be displayed on the screen 707.

[0062] While in the fifth embodiment, the transmitted light from the projection lens 705 is reflected only at the aberration-correcting reflection mirror 706, for example, as shown in the first embodiment, the transmitted light from the projection lens 705 can be reflected at aberration-correcting the reflection mirror 706 and a plane mirror respectively to project it on the screen 707.

[0063]

[EFFECT OF THE INVENTION] In the structure that magnifies the image via a lens for projection, aberration generated at the lens can be corrected by reflecting an image containing the aberration at the reflection mirror of a predetermined shape. Therefore, an image containing the least aberration can be projected on a large screen.

[0064] In other words, a reflection surface of a predetermined shape is introduced in an optical system to correct the aberration generated in the lens system by the reflection surface. This magnifies the image as well as simplifies the entire structure.

[0065] In addition, since a structure that has a lens which generates the aberration is admitted, the lens system to be used can be made simple. Further, a low-cost lens can be available.

[0066] Further, in a case where the reflection surface is used, since it is free from a problem (generally called as chromatic aberration) caused by difference in refractive index due to

wavelength, an image can be magnified for displaying it on the large screen, thereby magnifying the image so as to display it on the large screen.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 shows a schematic diagram of a projection-type display apparatus.

Fig. 2 shows a schematic diagram of a conventional display apparatus.

Fig. 3 shows a schematic diagram of a projection-type display apparatus.

Fig. 4 shows a schematic diagram of a projection-type display apparatus.

Fig. 5 shows a schematic diagram of a principle of image projection.

Fig. 6 shows a schematic diagram of a projection-type display apparatus.

Fig. 7 shows a schematic diagram of a projection-type display apparatus.

[DESCRIPTION OF THE REFERENCE NUMERALS]

10 ... cabinet

11 ... light source

12 ... liquid crystal panel

13 ... projection lens

14 ... reflection mirror of predetermined shape

15 ... plane reflection mirror

16 ... screen (projection surface)

21 ... light source

22 ... light from light source

23 ... liquid crystal panel

24 ... projection lens

25 ... screen (projection surface)

26 ... radial direction

301 ... light source

302 to 304 ... dichroic mirror

305 ... liquid crystal panel

306 ... mirror

307, 308 ... semitransmission mirror

309 ... projection lens

310 ... reflection mirror of predetermined shape

311 ... plane reflection mirror

312 ... screen (projection surface)

501, 502 ... liquid crystal panel

503, 504 ... lens

505, 506 ... lens

507 ... reflection surface

508 ... screen (projection surface)

702a to 702d ... dichroic mirror

304a to 702c ... liquid crystal panel

705 ... projection lens

706 ... reflection mirror

[Fig. 1]

16 ... screen

15 ... mirror

12 ... liquid crystal panel

14 ... mirror

[Fig. 6]

606 ... screen

605 ... mirror

602 ... liquid crystal panel

604 ... mirror